METHOD FOR THE DETERMINATION OF PM_{10} AND $PM_{2.5}$ EMISSIONS

(CONSTANT SAMPLING RATE PROCEDURES)

1. SCOPE AND APPLICABILITY

This method describes the procedure that you--the tester--must follow to measure

particulate matter emissions equal to or less than a nominal aerodynamic diameter of 10μm

(PM_{10}) and 2.5μm ($PM_{2.5}$). You may use this method only with stationary sources.

1.1   Who must use this method?

Our emission factor program has identified the following sources as typical PM emitters

where this method is applicable:

(a)   Industrial boilers

(b)   Fossil-fuel-fired steam generators (FFFSGs)

(c)   Kilns

(d)   Clinker coolers

(e)   Finish mills

(f)   Raw mills

(g)   Coal mills

(h)   Silos

(i)   Bagging operations

(j)   Rail and truck load-out operations

1.2   What can I measure with this method?

Use this method to measure PM_{10} and $PM_{2.5}$ using an in-stack measurement device.

1.3   Can I use this method to measure condensible emissions?

       You can't use this method to measure condensible emissions. We recognize that

condensible emissions are also PM_{10} and $PM_{2.5}$, but this in-stack method measures only the

component of particulate matter emissions that are solid or liquid at stack conditions. You must

use Method 202 of appendix M to 40 CFR part 51 in combination with this method (or Method

201 of appendix M to 40 CFR part 51), to measure total PM_{10} and $PM_{2.5}$ emissions.

1.4   What am I responsible for?

       You are responsible for obtaining the equipment and supplies you will need in this method.

You must also develop your own procedures for following this method and any additional

procedures to ensure accurate sampling and analytical measurements.

1.5   How can I ensure reliable results?

       To obtain reliable results, you must have a thorough knowledge of the test methods that

appear in the following list.

   (a)   Method 2 of Appendix A to 40 CFR part 60 - Determination of Stack Gas Velocity

         and Volumetric Flow Rate (Type S Pitot Tube).

   (b)   Method 1 of Appendix A to 40 CFR part 60 - Sample and Velocity Traverses for

         Stationary Sources.

   (c)   Method 3 of Appendix A to 40 CFR part 60 - Gas Analysis for Carbon Dioxide,

         Oxygen, Excess Air, and Dry Molecular Weight.

   (d)   Method 4 of Appendix A to 40 CFR part 60 - Determination of Moisture Content in

         Stack Gases.

(e)   Method 5 of Appendix A to 40 CFR part 60 - Determination of Particulate Emissions

from Stationary Sources.

(f)   Method 201A of Appendix M to 40 CFR part 51 - Determination of PM_{10} Emissions

(Constant Sampling Rate Procedures).

(g)   Method 202 of Appendix M to 40 CFR part 51 - Determination of Condensible

Particulate Emissions from Stationary Sources.

1.6   Do I need to incorporate additional test methods to measure ambient source contribution

for particulate?

We don't anticipate that you will need additional test methods to measure ambient source

contributions because these contributions are insignificant for most of the sources using this test

method. However, when an adjustment for the ambient air particulate is needed, use the ambient

air reference methods to quantify the ambient air contribution. Particulate collected by the

ambient air samplers that vaporize at the process temperature require additional adjustments.

1.7   Can I use this method to measure emissions following a wet scrubber?

You can't use this method to measure emissions following a wet scrubber because this

method is not applicable for in-stack gases containing water droplets. Stacks with entrained

moisture droplets may have water droplets larger than the cut sizes for the cyclones and these

water droplets normally contain particles that are PM_{10} and $PM_{2.5}$. To measure PM_{10} and $PM_{2.5}$

in emissions where water droplets are known to exist, we recommend that you use Method 5 of

Appendix A to 40 CFR part 60 (or a comparable method) and consider the particulate catch to be

PM_{10} and $PM_{2.5}$ emissions.

1.8   Under what conditions can I use this method as an alternative to EPA Method 17 or EPA

      Method 5?

      Technically, you can use this method to obtain both particle sizing and total filterable

particulate if the isokinetics are within 90-110 percent, the number of sampling points are the

same as Method 17 of Appendix A to 40 CFR part 60 or Method 5 of Appendix A to 40 CFR

part 60 requirements, and the filter temperature is within the acceptable range. However, to

satisfy Method 5 criteria, you may need to remove the in-stack filter and use an out-of-stack

filter and recover the probe between the $PM_{2.5}$ particle sizer and the filter. Additionally, to

satisfy Method 5 and Method 17 criteria, you may need to sample from more than 12 traverse

points. The increased number of sampling points may require the use of multiple nozzles to

maintain isokinetics between 90 and 110 percent and to maintain the minimum/maximum

nozzle/stack velocity ratios within acceptable ranges. Be aware that this method determines in-

stack PM_{10} and $PM_{2.5}$ emissions by sampling from a recommended maximum of 12 sample

points, at a constant flow rate through the train (the constant flow is necessary to maintain the

size cuts of the cyclones), and with a filter that is at the stack temperature. A Method 17 of

Appendix A to 40 CFR part 60 or Method 5 of Appendix A to 40 CFR part 60 train is operated

isokinetically (with varying flow rates through the train), samples from as many as 24 sample

points, and for Method 5 of Appendix A to 40 CFR part 60 an out-of-stack filter is maintained at

a constant temperature of 248°F. Further, to use this method in place of Method 17 of Appendix

A to 40 CFR part 60 or Method 5 of Appendix A to 40 CFR part 60, you must extend the

sampling time so that the minimum mass that you can weigh is collected on each of the portions

of this sampling train. Also, if you are using this method as an alternative to a required

performance test, you must receive approval from the appropriate authorities prior to conducting

the test.

2. SUMMARY OF METHOD

To measure PM_{10} and $PM_{2.5}$, extract a sample of gas at a predetermined constant flowrate

through an in-stack sizing device. The sizing device separates particles with nominal

aerodynamic diameters of PM_{10} and $PM_{2.5}$. To minimize variations in the isokinetic sampling

conditions, you must establish well-defined limits. Once a sample is obtained, remove

uncombined water from the particulate. Then use gravimetric analysis to determine the

particulate mass for each size fraction. Figure 1 of the Tables, Diagrams, Flowcharts, and

Validation Data section of this method presents the schematic of this process.

This method combines Method 201A of Appendix M to 40 CFR part 51 with the $PM_{2.5}$

cyclone from a conventional five-stage cascade cyclone train that includes five cyclones of

differing diameters in series. Insert the $PM_{2.5}$ cyclone between the PM_{10} cyclone and the filter

of the sampling train defined by Method 201A of Appendix M to 40 CFR part 51. Without the

addition of the $PM_{2.5}$ cyclone, the sampling train used in this method is the same sampling train

found in Method 201A of Appendix M to 40 CFR part 51.

3. DEFINITIONS

[Reserved]

4. INTERFERENCES/LIMITATIONS

[Reserved]

5. SAFETY

Disclaimer. You may have to use hazardous materials, operations, and equipment while

performing this method. We do not provide information on appropriate safety and health

practices. You are responsible for determining the applicability of regulatory limitations and

establishing appropriate safety and health practices. Handle materials and equipment properly.

6. EQUIPMENT AND SUPPLIES

6.1 What equipment do I need for the sampling train?

Figure 2 of the Tables, Diagrams, Flowcharts, and Validation Data section of this method

presents a sampling train schematic for use in this test method. This sampling train is the same

sampling train described in Method 17 of Appendix A to 40 CFR part 60 with the exception of

the PM_{10} and $PM_{2.5}$ sizing devices and in-stack filter. The following paragraphs describe the

sampling train's primary design features in detail.

6.1.1   Nozzle. You must use nozzles that are stainless steel (316 or equivalent) or

           Teflon®-coated stainless steel with a sharp tapered leading edge. We

           recommend that you choose one of the 12 nozzles listed in Figure 3 of the

           Tables, Diagrams, Flowcharts, and Validation Data section of this method

           because they meet design specifications. However, if you don't choose a nozzle

           from this list, then you must choose a nozzle that meets the criteria in paragraph

           5.2 of EPA Method 201A of Appendix M to 40 CFR part 51. We also

           recommend that you have a large number of nozzles in small diameter

           increments available to increase the likelihood of using a single nozzle for the

           entire traverse.

6.1.2   <u>PM_{10} and $PM_{2.5}$ sizer</u>. Choose a stainless steel (316 or equivalent) PM_{10} and

          $PM_{2.5}$ sizer. The sizing devices must be cyclones which meet the design

          specifications shown in Figures 3 and 4 of the Tables, Diagrams, Flowcharts,

          and Validation Data section of this method. Use a caliper to verify the

          dimensions of the PM_{10} and $PM_{2.5}$ sizers to within $\pm$ 0.02 cm of the design

          specifications. Example suppliers of PM_{10} and $PM_{2.5}$ sizers are:

          (a)   Environmental Supply Company, Inc.

                 2142 Geer Street

                 Durham, North Carolina 27704

                 (919) 956-9688

                 (919) 682-0333 (Fax)

          (b)   Apex Instruments

                 P.O. Box 727

                 125 Quantum Street

                 Holly Springs, North Carolina 27540

                 (919) 557-7300

                 (919) 557-7110 (Fax)

          (c)   Andersen Instruments Inc.

                 500 Technology Court

                 Smyrna, Georgia 30082

                 (770) 319-9999

                 (770) 319-0336 (Fax)

6.1.3   Filter holder. You must use a filter holder that is either stainless steel (316 or

equivalent) or Teflon®-coated stainless steel. Commercial size filter holders are

available depending upon project requirements. You should be able to find a

commercial filter holder to support 25-mm, 47-mm, and 63-mm diameter filters.

Commercial size filter holders contain a Teflon® O-ring, stainless steel screen

which supports the filter, and a final Teflon® O-ring. Screw the assembly

together and attach to the outlet of cyclone IV.

6.1.4   Pitot tube. You must use a pitot tube made of heat resistant tubing. Attach the

pitot tube to the probe with stainless steel fittings. Follow the specifications for

the pitot tube and its orientation to the inlet nozzle given in paragraph 6.1.1.3 of

Method 5 of Appendix A to 40 CFR part 60.

6.1.5   Probe liner. You do not have to use a probe liner. However, if you choose to do

so, follow the specifications in paragraph 6.1.1.2 of Method 5 of Appendix A to

40 CFR part 60.

6.1.6   Differential pressure gauge, condensers, metering systems, barometer, and gas

density determination equipment. Follow the requirements in paragraphs 6.1.1.4

through 6.1.3 of Method 5 of Appendix A to 40 CFR part 60, as applicable.

6.2 What equipment do I need for sample recovery?

You will need the following equipment to quantitatively determine the amount of

particulate matter recovered from the sampling train. Follow the requirements specified in

paragraphs 6.2.1 through 6.2.8 of Method 5 of Appendix A to 40 CFR part 60, respectively.

(a)   Filter holder brushes

(b)   Wash bottles

(c)   Glass sample storage containers

(d)   Petri dishes

(e)   Graduated cylinders and balance

(f)   Plastic storage containers

(g)   Funnel

(h)   Rubber policeman

7. REAGENTS AND STANDARDS

7.1 What reagents do I need for sample collection?

To collect a sample you will need a filter, silica gel, and stopcock grease. You must also

have water and crushed ice. You will find additional information on each of these items in the

following summaries.

7.1.1   Filter. You must use a glass fiber, quartz, or Teflon® filter that does not a have

an organic binder. The filter must also have an efficiency of at least 99.95

percent (<0.05 percent penetration) on 0.3 micron dioctyl phthalate smoke

particles. Conduct the filter efficiency test in accordance with ASTM Method D

2986-71, 78, 95a (incorporated by reference). Alternatively, you may use test

data from the supplier's quality control program. If the source you are sampling

has SO_2 or SO_3 emissions, you must use a filter that will not react to SO_2 or

SO_3. Depending on your application and project data quality objectives

(DQOs), filters are commercially available in 25-mm, 47-mm, and 63-mm

sizers.

7.1.2   <u>Silica gel</u>. You must choose an indicating-type silica gel of 6 to 16 mesh. We

must approve other types of desiccants (equivalent or better) before you use

them. Allow the silica gel to dry for 2 hours at 175°C (350°F) if it is being

reused. You do not have to dry new silica gel.

7.1.3   <u>Water (optional)</u>. Use deionized distilled water (to conform to ASTM D 1193-

77, 91 Type 3) to recover material caught in the impinger, if required. If you use

water to recover this material, then you must run blanks before you begin your

testing. Running blanks before field use will verify low blank concentrations

therby reducing the potential for a high field blank on test samples.

7.1.4   <u>Crushed ice</u>. Obtain this from the best readily available source.

7.1.5   <u>Stopcock grease (optional)</u>. The stopcock grease must be a heat-stable silicone

grease that is acetone-insoluble. This is not necessary if you are using screw-on

connectors with Teflon® sleeves, or similar.   We must approve other types of

stopcock grease before you use them.

7.2 What reagents do I need for sample recovery?

You must use acetone, reagent grade, $\leq$ 0.001 percent residue that is stored in glass bottles.

Do not use acetone from metal containers because it normally has a high residue blank. We are

aware that suppliers may transfer acetone to glass bottles from metal containers. Therefore you

must run acetone blanks prior to field use to make sure your acetone has a low blank value. Do

not subtract a blank value greater than 0.001 weight percent of acetone used from the sample

weight.

7.3 What reagents do I need for sample analysis?

You will need acetone and anhydrous calcium sulfate for the sample analysis. Refer to the

following summaries for additional information.

7.3.1   Acetone. Refer to paragraph 2.0 of this section.

7.3.2   Desiccant. Use indicating-type anhydrous calcium sulfate. We must approve

other desiccants before you use them.

8. SAMPLE COLLECTION, PRESERVATION, STORAGE, AND TRANSPORT

8.1 What qualifications do I need to perform this test method?

This is a complex test method. To obtain reliable results, you must be trained and

experienced with in-stack filtration systems (such as, cyclones, impactors, and thimbles) and

their operations.

8.2 What preparations must I do prior to the test?

Follow the pretest preparation instructions in paragraph 8.1 of Method 5 of Appendix A to

40 CFR part 60.

8.3 What must I determine to properly set up the test?

You must perform the following items to properly set up for this test:

(a)   Determine the sampling site location and traverse points.

(b)   Calculate probe/cyclone blockage.

(c)   Verify the absence of cyclonic flow.

(d)   Complete a preliminary velocity profile and select a nozzle(s).

8.3.1   <u>Sampling site location and traverse point determination</u>. Follow the standard

procedures in Method 1 of Appendix A to 40 CFR part 60 to select the

appropriate sampling site. Then do all of the following:

(a)   *Sampling site.* Choose a location that maximizes the distance from

upstream and downstream flow disturbances.

(b)   *Traverse points*. Select the same number of traverse points described in

paragraph 4.1.2 of Method 201A of Appendix M to 40 CFR part 51 and

shown in Figure 5 of the Tables, Diagrams, Flowcharts, and Validation

Data section of this method. The recommended maximum number of

traverse points at any location is 12. Prevent the disturbance and capture

of any solids accumulated on the inner wall surfaces by maintaining a 1

inch distance from the stack wall (½ inch for sampling locations less than

24 inches in diameter).

(c)   *Round or rectangular duct or stack.* If a duct or stack is round with two

ports located 90° apart, use six sampling points on each diameter. Use a

3x4 sampling point layout for rectangular ducts or stacks. Consult with

the administrator to receive approval for other layouts before you use

them.

(d)   *Sampling ports*. You will need new sampling ports in most of the

sampling port locations installed for sampling by Method 5 of Appendix A

to 40 CFR part 60 or Method 17 of Appendix A to 40 CFR part 60 for

total filterable particulate sampling. When you must use nozzles smaller

than 0.16 inch in diameter, the sampling port diameter must be 6 inches.

Do not use the conventional four inch diameter port because it will not

support the length of the nozzle extending from the PM_{10} cyclone. [**Note:**

If the port nipple is short, you may be able to "hook" the sampling head

through a smaller port into the duct or stack.]

8.3.2   Probe/cyclone blockage calculations. Following the procedures in the next two

paragraphs, as appropriate.

8.3.2.1   *Ducts with diameters greater than 24 inches*. Minimize the blockage

effects of the combination of the in-stack nozzle/cyclones and filter

assembly for ducts with diameters greater than 24 inches by keeping the

cross-sectional area of the assembly at 3 percent or less of the cross-

sectional area of the duct.

8.3.2.2   *Ducts with diameters between 24 and 18 inches*. Ducts with diameters

between 24 inches to 18 inches have blockage effects ranging from 3

percent to 6 percent, as illustrated in Figure 7 of the Tables, Diagrams,

Flowcharts, and Validation Data section of this method. Therefore, when

you conduct tests on these small ducts, you must adjust the observed

velocity pressures for the estimated blockage factor whenever the

combined sampling apparatus blocks more than 3 percent of the stack or

duct (see paragraphs 7.2.2 and 7.2.3 of this section on the probe blockage

factor and the final adjusted velocity pressure, respectively).

8.3.3   Cyclonic flow. Do not use the combined cyclone sampling head at sampling

locations subject to cyclonic flow. Also, you must follow Method 2 procedures

to determine the presence or absence of cyclonic flow. Then perform the

following calculations. [**Note:** You can minimize cyclonic flow conditions by

placing gas flow straighteners upstream of the sampling location.]

(a)   *Find the angle that has a null velocity pressure.* Insert the S-type pitot

tube at each of the traverse points and rotate until you locate the angle that

has a null velocity pressure.

(b)   *Determining a sampling location.* Average the absolute values of the

angles that have a null velocity pressure. Do not use the sampling location

if the average absolute value exceeds 20°.

8.3.4   Preliminary velocity profile. Conduct a preliminary Method 2 of Appendix A to

40 CFR part 60 velocity traverse, as well as the measurements below. The

purpose of the velocity profile is to determine all of the following:

(a)   The gas sampling rate for the combined probe/cyclone sampling head.

(b)   The appropriate nozzle(s) to maintain the required velocity pressure range

and isokinetic range.

(c)   The necessary sampling duration to obtain sufficient particulate catch

weights.

8.3.4.1   *Preliminary traverse.* You must use an S-type pitot tube with a

conventional thermocouple to conduct the traverse. Conduct the

preliminary traverse as close as possible to the anticipated testing time on

sources that are subject to hour-by-hour gas flow rate variations of

approximately ±20% and/or gas temperature variations of approximately

±50°F. Follow the following instructions. [**Note:** You should be aware

that these variations can cause errors in the cyclone cut diameters and the

isokinetic sampling velocities.]

8.3.4.2   *Velocity pressure range*. Insert the S-type pitot tube at each traverse point

and record the range of velocity pressures measured on the Method 2 of

Appendix A to 40 CFR part 60 data form. You will use this later to select

the appropriate nozzle(s).

8.3.4.3   *Initial gas stream viscosity and molecular weight*. Determine the average

gas temperature, average gas oxygen content, average carbon dioxide

content, and estimated moisture content. You will use this information to

calculate the initial gas stream viscosity (Equation 3) and molecular

weight (Equations 1 and 2). [**Note:** You must follow the instructions

outlined in Method 4 to estimate the moisture content. You may use a wet

bulb-dry bulb measurement or hand-held hygrometer measurement to

estimate the moisture content of sources with gas temperatures less than

160°F.]

8.3.4.4   *Particulate matter concentration in the gas stream.* Determine the

particulate matter concentration in the gas stream through qualitative

measurements or estimates. Having an idea of what the particulate

concentration is in the gas stream will help you determine the appropriate

sampling time to acquire sufficient particulate matter weight for better

accuracy at the source emission level. The collectable particulate matter

weight requirements depend primarily on the types of chemical analyses

needed to characterize the emissions. Estimate the collectable particulate

matter concentrations in the $^>10$ micrometer, ≤ 10 and $^> 2.5$ micrometers,

and ≤ 2.5 micrometer size ranges.

8.4   Why must I perform pre-test calculations.

You must perform pre-test calculations to help select the appropriate gas sampling rate

through cyclone I (PM_{10}) and cyclone IV ($PM_{2.5}$). Choosing the appropriate sampling rate will

allow you to maintain the appropriate particle cut diameters based upon preliminary gas stream

measurements, as specified in Table 2 of the Tables, Diagrams, Flowcharts, and Validation Data

section of this method.

8.4.1   Gas sampling rate. The gas sampling rate is defined by the performance curves

for both cyclones, as illustrated in Figure 8 of the Tables, Diagrams, Flowcharts,

and Validation Data section of this method. You must use the calculations in

paragraph 5 of this section to achieve the appropriate cut size specification for

each cyclone. The optimum gas sampling rate is the overlap zone defined as the

range below the cyclone IV 2.25 micrometer curve down to the cyclone I 11.0

micrometer curve (area between the two dark, solid lines in Figure 8 of the

Tables, Diagrams, Flowcharts, and Validation Data section of this method).

8.4.2   Choosing the appropriate sampling rate. You must select a gas sampling rate in

the middle of the overlap zone (discussed in paragraph 4.1 of this section), as

illustrated in Figure 8 of the Tables, Diagrams, Flowcharts, and Validation Data

section of this method to maximize the acceptable tolerance for slight variations

in flow characteristics at the sampling location. The overlap zone is also a weak

function of the gas composition. [**Note:** You should be aware that the

acceptable range is limited, especially for gas streams with temperatures less

than approximately 100°F.]

8.5   What pre-test calculations must I perform?

You must perform all of the calculations in Table 1 of this paragraph, and the calculations

described in paragraphs 8.5.1 through 8.5.5 of this section.

Table 1. Pretest Calculations

If you are using...	To calculate...	Then use...
Preliminary data	dry gas molecular weight, M_d	Equation 1
Dry gas molecular weight (M_d) and preliminary moisture content of the gas stream	wet gas molecular weight, M_W	Equation 2[a]
Stack gas temperature, and oxygen and moisture content of the gas stream	gas viscosity, μ	Equation 3
Gas viscosity, μ	Cunningham correction factor[b], C	Equation 4
Reynolds Number[c] (N_{re}) $N_{re} < 3162$	preliminary lower limit cut diameter for cyclone I, D_{50LL}	Equation 5
D_{50LL} from Equation 5	cut diameter for cyclone I for middle of the overlap zone, D_{50T}	Equation 6

Table 1. Pretest Calculations

If you are using...	To calculate...	Then use...
D_{50T} from Equation 6	final sampling rate for cyclone I, $Q_I(Q_s)$	Equation 7
$Q_I(Q_s)$ from Equation 7	(verify) the assumed Reynolds number	Equation 8

[a] Use Method 4 of Appendix A to 40 CFR part 60 to determine the moisture content of the stack

gas. Use a wet bulb-dry bulb measurement device or hand-held hygrometer to estimate moisture

content of sources with gas temperature less than 160°F.

[b] For the lower cut diameter of cyclone IV, 2.25 micrometer.

[c] Verify the assumed Reynolds number using the procedure in paragraph 5.1, below, before

proceeding to Equation 9.

8.5.1   The assumed Reynolds number. Verify the assumed Reynolds number (N_{re}) by

substituting the sampling rate (Q_s) calculated in Equation 7 into Equation 8.

Then use Table 2 of this paragraph to determine if the N_{re} used in Equation 5

was correct.

Table 2. Verification of the Assumed Reynolds Number

If the N_{re} is ...	Then ...	And ...
< 3162	Calculate ΔH for the meter box	
≥ 3162	Recalculate D_{50LL} using	Substitute the "new" D_{50LL} into
	Equation 10	Equation 6 to recalculate D_{50T}

8.5.2   Final sampling rate. You must recalculate the final sampling rate(Q_s) if the

           assumed Reynold's number used in your initial calculation is not correct. Use

           Equation 7 to recalculate the optimum sampling rate (Q_s).

8.5.3   Meter box ΔH. Use Equation 9 to calculate the meter box ΔH after you calculate

           the optimum sampling rate and confirm the Reynolds number. [**Note:** The stack

           gas temperature may vary during the test which could affect the sampling rate.

           If this occurs, you must make slight adjustments in the meter box ΔH to maintain

           the correct constant cut diameters. Therefore, use Equation 9 to recalculate the

           ΔH values for 50°F above and below the stack temperature measured during the

           preliminary traverse (see paragraph 3.4.1 of this section) and document this

           information in the Tables, Diagrams, Flowcharts, and Validation Data section of

           this method under Table 3.]

8.5.4   Choosing a sampling nozzle. You must select one or more nozzle sizes to

           provide for near isokinetic sampling rate (that is, 80% to 120%). This will also

           minimize anisokinetic sampling errors for the 10 micrometer particles at each

           point. First calculate the mean stack gas velocity, v_s, using Equation 11. Look

           at paragraph 7.2 of this section for information on correcting for blockage and

           use of different pitot tube coefficients. Then use Equation 12 to calculate the

           diameter of a nozzle that provides for isokinetic sampling at the mean stack gas

           velocity at flow Q_s. From the available nozzles just smaller and just larger of

           this diameter, D, select the most promising nozzle(s). Perform the following

           steps for the selected nozzle(s).

8.5.4.1   *Minimum/maximum nozzle/stack velocity ratio*. Use Equation 14 to

calculate the minimum nozzle/stack velocity ratio, R_{min}. Use Equation 15

to calculate the maximum nozzle/stack velocity ratio, R_{max}.

8.5.4.2   *Minimum gas velocity*. Use Equation 16 to calculate the minimum gas

velocity (v_{min}) if R_{min} is an imaginary number (negative value under the

square root function) or if R_{min} is less than 0.5. Use Equation 17 to

calculate v_{min} if R_{min} is greater than or equal to 0.5.

8.5.4.3   *Maximum stack velocity*. Use Equation 18 to calculate the maximum

stack velocity (v_{max}) if R_{max} is less than 1.5. Use Equation 19 to calculate

the stack velocity if R_{max} is greater than or equal to 1.5.

8.5.4.4   *Conversion of gas velocities to velocity pressure.* Use Equation 20 to

convert v_{min} to minimum velocity pressure, Δp_{min}. Use Equation 21 to

convert v_{max} to maximum velocity pressure, Δp_{max}.

8.5.4.5   Compare minimum and maximum velocity pressures with the observed

velocity pressures at all traverse points during the preliminary test (see

paragraph 3.4.2 of this section).

8.5.5   Optimum sampling nozzle. The nozzle you selected is appropriate if all the

observed velocity pressures during the preliminary test fall within the range of

the Δp_{min} and Δp_{max}. Make sure the following requirements are met. Then

follow the procedures in paragraphs 5.5.1 and 5.5.2 of this section.

(a)   Choose an optimum nozzle that provides for isokinetic sampling

conditions as close to 100% as possible. This is prudent because even if

there are slight variations in the gas flow rate, gas temperature, or gas

composition during the actual test, you have the maximum assurance of

satisfying the isokinetic criteria. Generally, one of the two candidate

nozzles selected will be closer to optimum (see paragraph 5.4 of this

section).

      (b)   You can only have one point that is outside the minimum-to-maximum

range. However, you can select two or more nozzles to achieve the

isokinetic specification.

8.5.5.1   *Precheck*. Visually check the selected nozzle for dents before use.

8.5.5.2   *Attach the pre-selected nozzle*. Screw the pre-selected nozzle onto the

main body of cyclone I using Teflon$^{®}$ tape. Use a union and cascade

adaptor to connect the cyclone IV inlet to the outlet of cyclone I (see

Figure 2 of the Tables, Diagrams, Flowcharts, and Validation Data section

of this method).

8.6 How do I prepare the sampling train?

First, you must assemble the train and complete the leak check on the combined cyclone

sampling head and pitot tube. Use the following procedures to prepare the sampling train.

[**Note:** Do not contaminate the sampling train during preparation and assembly. You must keep

all openings where contamination can occur covered until just prior to assembly or until

sampling is about to begin.]

8.6.1   Sampling head and pitot tube. Assemble the combined cyclone train. The O-

rings used in the train have a temperature limit of approximately 400°F.

However, Teflon® O-rings can withstand 600°F without sealing problems. You

must use cyclones with stainless steel sealing rings when stack temperatures

exceed 600°F. You must also keep the nozzle covered to protect it from nicks

and scratches.

8.6.2   Filter holder and pitot tube. Attach the pre-selected filter holder to the end of the

combined cyclone sampling head (see Figure 2 of the Tables, Diagrams,

Flowcharts, and Validation Data section of this method). You must number and

tare the filter before use. Attach the S-type pitot tube to the combined cyclones

after the sampling head is fully attached to the end of the probe. [**Note:** The pitot

tube tip must be mounted (1) slightly beyond the combined head cyclone

sampling assembly and (2) at least one inch off the gas flow path into the

cyclone nozzle. This is similar to the pitot tube placement in Method 17 of

Appendix A to 40 CFR part 60.] Weld the sensing lines to the outside of the

probe to ensure proper alignment of the pitot tube. Provide unions on the

sensing lines so that you can connect and disconnect the S-type pitot tube tips

from the combined cyclone sampling head before and after each run. [**Note:**

Calibrate the pitot tube on the sampling head because the cyclone body is a

potential source of interference.]

8.6.3   Filter. Use tweezers or clean disposable surgical gloves to place a labeled

(identified) and pre-weighed filter in the filter holder. You must center the filter

and properly place the gasket so that the sample gas stream will not circumvent

the filter. Check the filter for tears after the assembly is completed. Then screw

the filter housing together to prevent the seal from leaking.

8.6.4   Leak check. Use the procedures outlined in paragraph 8.4 of Method 5 of

Appendix A to 40 CFR part 60 to leak check the entire sampling system.

Specifically perform the following procedures:

   8.6.4.1   *Sampling train*. You must pretest the entire sampling train for leaks. The

               pretest leak check must have a leak rate of not more than 0.02 ACFM or

               4% of the average sample flow during the test run, whichever is less.

               Additionally, you must conduct the leak check at a vacuum equal to or

               greater than the vacuum anticipated during the test run. Enter the leak

               check results on the field test data sheet for the specific test. [**Note:** Do

               not conduct a leak check during port changes.]

   8.6.4.2   *Pitot tube assembly*. After you leak check the sample train, you must

               perform a leak check of the pitot tube assembly. Follow the procedures

               outlined in paragraph 8.4.1 of Method 5 of Appendix A to 40 CFR part 60.

8.6.5   Sampling head. You must preheat the combined sampling head to the stack

temperature of the gas stream at the test location (± 10°C). This will heat the

sampling head and prevent moisture from condensing from the sample gas

stream. Record the site barometric pressure and stack pressure on the field test

data sheet.

   8.6.5.1   *Unsaturated stacks*. You must complete a passive warmup (of 30-40 min)

               within the stack before the run begins to avoid internal condensation.

[**Note:** Unsaturated stacks do not have entrained droplets and operate at

temperatures above the local dew point of the stack gas.]

8.6.5.2   *Shortened warm-up of unsaturated stacks*. You can shorten the warmup

time by unthermostated heating outside the stack (such as by a heat gun).

Then place the heated sampling head inside the stack and allow the

temperature to equilibrate.

8.7 How do I operate the sample train?

You must follow the procedures outlined in paragraph 4.1.5 of Method 201A of Appendix

M to 40 CFR part 51 to operate the sample train. You perform the following procedures:

8.7.1   Sample point dwell time. You must calculate the dwell time (that is, sampling

time) for each sampling point to ensure that the overall run provides a velocity-

weighted average that is representative of the entire gas stream. The dwell time

calculations are identical to those used in paragraph 4.1.2.2.5 of Method 201A of

Appendix M to 40 CFR part 51.

8.7.1.1   *Dwell time at first sampling point*. Calculate the dwell time for the first

point, t_1, using Equation 22. You must use the data from the preliminary

traverse. Here, N equals the total number of traverse points.

8.7.1.2   *Dwell time at remaining sampling points*. Calculate the dwell time at each

of the remaining traverse points, t_n, using Equation 23. This time you

must use the actual test run data. [**Note:** Round the dwell times to 1/4

minutes.] Each traverse point must have a dwell time of at least two

minutes.

8.7.2   <u>Adjusted velocity pressure</u>. When selecting your sampling points using your

preliminary velocity traverse data, your preliminary velocity pressures must be

adjusted to take into account the increase in velocity due to blockage. Also, you

must adjust your preliminary velocity data for differences in pitot tube

coefficients. Use the following instructions to adjust the preliminary velocity

pressure.

    8.7.2.1   *Different pitot tube coefficient*. You must use Equation 24 to correct the

recorded preliminary velocity pressures if the pitot tube mounted on the

combined cyclone sampling head has a different pitot tube coefficient than

the pitot tube used during the preliminary velocity traverse (see paragraph

3.1 of this section).

    8.7.2.2   *Probe blockage factor*. You must use Equation 25 to calculate an average

probe blockage correction factor (b_f) if the diameter of your stack or duct

is between 18 and 24 inches. A probe blockage factor is calculated

because of the flow blockage caused by the relatively large cross-sectional

area of the combined cyclone sampling head, as discussed in paragraph

3.2 of this section and illustrated in Figure 7 of the Tables, Diagrams,

Flowcharts, and Validation Data section of this method. [**Note:** The

sampling head (including the filter holder) has a projected area of

approximately 20.5 square inches when oriented into the gas stream. As

the probe is moved from the most outer to the most inner point, the

amount of blockage that actually occurs ranges from approximately 4

square inches to the full 20.5 inches. The average cross-sectional area

blocked is 12 square inches.]

8.7.2.3   *Final adjusted velocity pressure*. Calculate the final adjusted velocity

pressure(Δp_{s2}) using Equation 26. [**Note:** Figure 7 of the Tables,

Diagrams, Flowcharts, and Validation Data section of this method

illustrates that the blockage effect of the large combined cyclone sampling

head increases rapidly below diameters of 18 inches. Therefore, you must

follow the procedures outlined in Method 1A to conduct tests in small

stacks (<18 inches diameter). You must conduct the velocity traverse

downstream of the sampling location or immediately before the test run.]

8.7.3   Sample train operation. You must follow the procedures outlined in paragraph

4.1.5 of Method 201A of Appendix M to 40 CFR part 51 to operate the sample

train. In addition to these procedures, you must also use running starts and stops

on both small and large stacks if the static pressure at the sampling location is

more negative than 5 in. water column (WC). This prevents back pressure from

rupturing the sample filter. If you use a running start, adjust the flow rate to the

calculated value after you perform the leak check (see paragraph 7.4 of this

section).

8.7.3.1   *Level and zero manometers*. Make periodic checks of the level and zero

point of the manometers during the traverse. Vibrations and temperature

changes may cause them to drift.

8.7.3.2   *Portholes*. Clean the portholes prior to the test run. This will minimize

the chance of collecting deposited material in the nozzle.

8.7.3.3   *Sampling procedures*. Verify that the combined cyclone sampling head

temperature is at stack temperature (± 10°C). Remove the protective

cover from the nozzle. To begin sampling, immediately start the pump

and adjust the flow to calculated isokinetic conditions. Position the probe

at the first sampling point with the nozzle pointing directly into the gas

stream. Ensure the probe/pitot tube assembly is leveled. [**Note:** When the

probe is in position, block off the openings around the probe and porthole

to prevent unrepresentative dilution of the gas stream.]

(a) You must traverse the stack cross-section, as required by Method 5 of

Appendix A to 40 CFR part 60. Do not bump the cyclone nozzle into

the stack walls when sampling near the walls or when removing or

inserting the probe through the portholes. This will minimize the

chance of extracting deposited materials.

(b) You must record the data required on the field test data sheet for each

run. Record the initial dry gas meter (DGM) reading. Then take a

DGM readings at the following times: (1) the beginning and end of

each sample time increment, (2) when changes in flow rates are made,

and (3) when sampling is halted. Compare the velocity pressure

measurements (Equations 20 and 21) with the velocity pressure

measured during the preliminary traverse. Keep the meter box ΔH at

the value calculated in paragraph 5.3 of this section for the stack

temperature that is observed during the test. Record all the point-by-

point data and other source test parameters on the field test data sheet.

Do not leak check the sampling system during port changes.

(c) Maintain the flow through the sampling system at the last sampling

point. Remove the sampling train from the stack while you are still

operating (running stop). Then stop the pump and record the final

DGM reading and other test parameters on the field test data sheet.

8.7.4   Process data. You must fully document the process and air pollution control

system operating conditions during the test. This is important. You will need

data and information on the process unit tested, the particulate control system

used to control emissions, and the sampling train conditions.

8.7.4.1   *Particulate control system data*. You will use the process and particulate

control system data to determine if representative operating conditions

were maintained throughout the testing period.

8.7.4.2   *Sampling train data*. You will use the sampling train data to confirm that

the measured particulate emissions are accurate and complete.

8.7.5   Sample recovery. First remove the sample head (combined cyclone/filter

assembly) from the stack gas. After the sample head is removed, you must

perform a post-test leak check of the probe and sample train. Then recover the

components from the cyclone/filter. Refer to the following summaries for more

detailed information.

8.7.5.1   *Remove sampling head*. At the conclusion of the test, document final test

conditions and remove the pitot tube and combined cyclone sampling head

from the source. Make sure that you do not scrape the pitot tube or the

combined cyclone sampling head against the port or stack walls. [**Note:**

After you stop the gas flow, make sure you keep the combined cyclone

head level to avoid tipping dust from the cyclone cups into the filter

and/or down-comer lines.] After cooling and when the probe can be

safely handled, wipe off all external surfaces near the cyclone nozzle and

cap the inlet to cyclone I. Remove the combined cyclone/filter sampling

head from the probe. Cap the outlet of the filter housing to prevent

particulate matter from entering the assembly.

8.7.5.2   *Leak check probe/sample train assembly*. Leak check the remainder of the

probe and sample train assembly (including meter box) after removing the

combined cyclone head/filter. You must conduct the leak rate at a vacuum

equal to or greater than the maximum vacuum achieved during the test

run. Enter the results of the leak check onto the field test data sheet. If

the leak rate of the sampling train (without the combined cyclone

sampling head) exceeds 0.02 ACFM or 4% of the average sampling rate

during the test run (whichever is less), the run is invalid and you must

repeat it.

8.7.5.3   *Recovery of particulate matter*. Recovery involves the quantitative

transfer of particles in the following size range: (1) greater than

10 micrometers, (2) less than or equal to 10 micrometers but greater than

2.5 micrometers, and (3) less than or equal to 2.5 micrometers. You must

use a Nylon brush and an ultrapure acetone rinse to recover particles from

the combined cyclone/filter sampling head. Use the following procedures

for each container.

Container #1 -   Use tweezers and/or clean disposable surgical gloves to

remove the filter from the filter holder. Place the filter in the petri dish

you identified as Container #1. Using a dry Nylon bristle brush and/or a

sharp-edged blade, carefully transfer any particulate matter and/or filter

fibers that adhere to the filter holder gasket or filter support screen to the

petri dish. Seal the container. This container holds particles less than 2.5

micrometers that are caught on the in-stack filter.

Container #2 - Quantitatively recover the (1) particulate matter from the

cyclone I cup and acetone rinses (and brush cleaning) of the cyclone cup,

(2) internal surface of the nozzle, and (3) cyclone I internal surfaces,

including the outside surface of the downcomer line. Seal the container

and mark the liquid level on the outside of the container. You must keep

any dust found on the outside of cyclone I and cyclone nozzle external

surfaces out of the sample. This container holds particulate matter greater

than 10 micrometers.

Container #3 - Place the solids from cyclone cup IV and the acetone (and

brush cleaning) rinses of the cyclone I turnaround cup (above inner

downcomer line), inside of the downcomer line, and interior surfaces of

cyclone IV into your #3 container. Seal the container and mark the liquid

level on the outside. This container holds particulate matter less than 10

micrometers and greater than 2.5 micrometers.

Container #4 - Retrieve the acetone rinses (and brush cleaning) of the exit

tube of cyclone IV and the front half of the filter holder in container #4.

Seal the container and mark the liquid level on the outside of the

container. This container holds particulate matter that is less than 2.5

micrometers.

Container #5 - Follow the recovery instructions for Container #3 from

paragraph 8.7.6.3 of Method 5 of Appendix A to 40 CFR part 60. This

container holds the silica gel.

Container #6 - Take 50 ml of the acetone directly from the wash bottle

you used, and place it in Container #6, labeled Acetone Rinse Blank.

Container #7 - Refer to paragraph 8.7.6.4 of Method 5 of Appendix A to

40 CFR part 60, under "Impinger Water" for instructions. This container

holds the Impinger Water.

8.7.6   Transport procedures. Containers must remain in an upright position at all times

during shipping. You do not have to ship the containers under dry or blue ice.

9. QUALITY CONTROL

9.1 What do I use to perform daily quality audits?

Conduct daily quality audits using data quality indicators that require review of (1)

recording and transfer of raw data, (2) calculations, and (3) documentation of testing procedures.

9.2 How do I verify the calculations?

Verify the calculations by independent, manual checks. You must flag any suspect data

and identify the nature of the problem and potential effect on data quality. After you complete

the test, prepare a data summary and compile all the calculations and raw data sheets.

9.3 When must I record operating conditions?

You must record any unusual process operating conditions or adverse weather conditions

that occur during testing. Discontinue the test if the operating conditions may cause non-

representative particulate emissions.

9.4 When must I develop a health and safety plan?

You must develop a health and safety plan to ensure the safety of your employees who are

on-site conducting the particulate emission test. Your plan must conform with all applicable

OSHA, MSHA, and DOT regulatory requirements. The procedures must also conform to the

plant health and safety requirements.

10. CALIBRATION AND STANDARDIZATION

[**Note**: Maintain a laboratory log of all calibrations.]

10.1 How do I measure the gas flow velocities?

Measure the gas flow velocities at the sampling locations using Method 2 of Appendix A to 40 CFR part 60. You must us an S-type pitot tube that meets the required EPA specifications (EPA Publication 600/4-77-0217b) during these velocity measurements. You must also:

(a)   Visually inspect the S-type pitot tube before sampling.

(b)   Leak check both legs of the pitot tube before and after sampling.

(c)   Maintain proper orientation of the S-type pitot tube while making measurements.

10.1.1   S-type pitot tube orientation. The S-type pitot tube is oriented properly when the yaw and the pitch axis are 90 degrees to the air flow.

10.1.2   Average velocity pressure record. Instead of recording either high or low values, record the average velocity pressure at each point during flow measurements.

10.1.3   Pitot tube coefficient. Determine the pitot tube coefficient based on physical measurement techniques described in Method 2 of Appendix A to 40 CFR part 60. [**Note:** You must calibrate the pitot tube on the sampling head because of potential interferences from the cyclone body. Refer to paragraph 7.2 under the Sample Collection, Preservation, Storage and Transport section of this method for additional information.]

10.2   What procedures must I follow to calibrate the thermocouples?

You must use the procedures described in paragraph 10.1.4.1.2 of Method 2 of Appendix A

to 40 CFR part 60 to calibrate the thermocouples. Calibrate each temperature sensor at a

minimum of three points over the anticipated range of use against an NIST-traceable mercury-in-

glass thermometer.

10.3 What types of nozzles must I use for sampling?

Use stainless steel (316 or equivalent) or Teflon®-coated nozzles for isokinetic sampling.

Make sure that all nozzles are thoroughly cleaned, visually inspected, and calibrated according to

the procedure outlined in paragraph 10.1 of Method 5 of Appendix A to 40 CFR part 60.

10.4   What procedures must I follow to calibrate the dry gas meter?

You must follow the calibration procedures documented in paragraph 16.1 of Method 5 of

Appendix A to 40 CFR part 60. Also, make sure you fully calibrate the dry gas meter to

determine the volume correction factor prior to field use. Post-test calibration checks must be

performed as soon as possible after the equipment has been returned to the shop. Your pretest

and post-test calibrations must agree within ±5 percent.

11. ANALYTICAL PROCEDURES

11.1 What procedures must I follow to record data?

Record all data on the analytical data sheet. You can obtain the data sheet from Figure 5-

6 of Method 5 of Appendix A to 40 CFR part 60.

11.2 What procedure must I follow for the container analysis?

Follow the analysis procedures outlined in paragraph 11.2 of Method 5 of Appendix A to

40 CFR part 60 and make the following exceptions:

(a)   Container #1 must be treated like Container #1 described in Method 5 of Appendix A

to 40 CFR part 60.

(b)   Containers #2, #3, #4, and #6 must be treated separately like Container #2 described

in Method 5 of Appendix A to 40 CFR part 60.

(c)   Container #5 must be treated like Container #3 described in Method 5 of Appendix A

to 40 CFR part 60.

12. CALCULATIONS AND DATA ANALYSIS

12.1 What do I need to calculate?

You need to perform all of the calculations found in Table 3 of this paragraph. Table 3 of

this paragraph also provides instructions and references for the calculations.

Table 3. Calculations for Recovery of PM_{10} and $PM_{2.5}$

Calculations	Instructions and References
Average dry gas meter temperature	See field test data sheet.
Average orifice pressure drop	See field test data sheet.
Dry gas volume (V_{ms})	Use Equation 27 to correct the sample volume measured by the dry gas meter to standard conditions (20°C, 760 mm Hg or 68°F, 29.92 in. Hg).
Dry gas sampling rate (Q_{sST})	Must be calculated using Equation 28.
Volume of water condensed (V_{ws})	Use Equation 29 to determine the water condensed in the impingers and silica gel combination. Determine the total moisture catch by measuring the change in volume or weight in the impingers and weighing the silica gel.

Table 3. Calculations for Recovery of PM_{10} and $PM_{2.5}$

Calculations	Instructions and References
Moisture content of stack gas (B_{ws})	Calculate this with Equation 30.
Gas sampling rate (Q_s)	Calculate this with Equation 31.
Test condition Reynolds number[1]	Use Equation 8 to calculate the actual Reynolds number during test conditions.
Actual D_{50} of Cyclone I	Calculate this with Equation 32. This calculation is based on the average temperatures and pressures measured during the test run.
Stack gas velocity (v_s)	Calculate this with Equation 11.
Percent isokinetic rate (%I)	Calculate this with Equation 40.

[1] Calculate the Reynolds number at the cyclone IV inlet during the test based on: (1) the

sampling rate for the combined cyclone head, (2) the actual gas viscosity for the test, and (3)

the dry and wet gas stream molecular weights.

12.2 What data must I analyze?

You must analyze D_{50} of Cyclone IV and the concentrations of the particulate matter in the

various size ranges.

12.2.1 D_{50} of cyclone IV. To determine the actual D_{50} for cyclone IV, you must

recalculate the Cunningham correction factor and the Reynolds number for the

best estimate of cyclone IV D_{50}. The following paragraphs summarize

additional information on how to recalculate the Cunningham correction factor

and determine which Reynold's number to use.

12.2.1.1   *Cunningham correction factor.* You must recalculate the initial estimate

of the Cunningham correction factor using the actual test data. Insert the

actual test run data and D_{50} of 2.5 micrometers into Equation 4. This will

give you a new Cunningham correction factor that is based on actual data.

12.2.1.2   *Initial D_{50} for cyclone IV.* Determine the initial estimate for cyclone IV

D_{50} using the test condition Reynolds number calculated with Equation 8

as indicated in Table 3 of this section. Refer to the following instructions.

(a) If the Reynold's number is less than 3162, calculate the D_{50} for

cyclone IV with Equation 33, using actual test data.

(b) If the Reynold's number is equal to or greater than 3162, calculate the

D_{50} for cyclone IV with Equation 34, using actual test data.

(c) Insert the "new" D_{50} value calculated by either Equation 33 or 34 into

Equation 35 to re-establish the Cunningham Correction Factor (C_r).

[**Note:** Use the test condition calculated Reynolds number to

determine the most appropriate equation (Equation 33 or 34).]

12.2.1.3   *Re-establish cyclone IV D_{50}.* Use the re-established Cunningham

correction factor (calculated in the previous step) and the calculated

Reynold's number to determine D_{50-1}.

(a) Use Equation 36 to calculate the re-established cyclone IV D_{50-1} if the

Reynolds number is less than 3162.

(b) Use Equation 37 to calculate the re-established cyclone IV D_{50-1} if the

Reynolds number is equal to or greater than 3162.

12.2.1.3   *Establishing "Z" values.* The "Z" value is the result of an analysis that

you must perform to determine if the Cunningham correction factor is

acceptable. Compare the calculated cyclone IV D_{50} (either Equation 33 or

34) to the re-established cyclone IV D_{50-1} (either Equation 36 or 37)

values based upon the test condition calculated Reynolds number

(Equation 38, refer to 2.1.2 for additional information). Follow these

procedures.

(a) Use Equation 38 to calculate the "Z". If the "Z" value is within 0.99

and 1.01, then the D_{50-1} value is the best estimate of the cyclone IV

D_{50} cut diameter for your test run.

(b) If the "Z" value is greater than 1.01 or less than 0.99, re-establish a

Cunningham correction factor based on the D_{50-1} value determined in

either Equations 36 or 37, depending upon the test condition

Reynolds number.

(c) Use the second revised Cunningham correction to re-calculate the

cyclone IV D_{50}.

(d) Repeat this iterative process as many times as necessary using the

prescribed equations until you achieve the criteria documented in

Equation 39.

12.2.2   <u>Particulate concentration</u>. Use the particulate catch weights in the combined

           cyclone sampling train to calculate the concentration of particulate matter in the

           various size ranges. You must correct the concentrations for the acetone blank .

    12.2.2.1   *Acetone blank concentration*. Use Equation 41 to calculate the acetone

                 blank concentration (C_a).

    12.2.2.2   *Acetone blank weight*. Use Equation 42 to calculate the acetone blank

                 weight (W_a). [**Note:** Correct each of the particulate matter weights per

                 size fraction by subtracting the acetone blank weight (that is, $M_{2,3,4}-W_a$)].

    12.2.2.3.   *Particulate weight catch per size fraction*. Subtract the weight of the

                 acetone blank from the particulate weight catch in each size fraction.

                 [**Note:** Do not subtract a blank value of greater than 0.001 percent of the

                 weight of the acetone used from the sample weight.] Use the following

                 procedures.

        (a) Use Equation 43 to calculate the particulate matter recovered from

             Containers #1, #2, #3, and #4. This is the total collectable particulate

             matter (C_{total}).

        (b) Use Equation 44 to determine the quantitative recovery of PM_{10}

             particulate matter (C_{PM10}) from Containers #1, #3, and #4.

        (c) Use Equation 45 to determine the quantitative recovery of $PM_{2.5}$

             particulate ($C_{PM2.5)}$ recovered from Containers #1 and #4.

12.3 What must I include in the emissions test report?

      You must include the following list of conventional elements in the emissions test report.

(a)   Emission test description including any deviations from this protocol

(b)   Summary data tables on a run-by-run basis

(c)   Flowchart of the process or processes tested

(d)   Sketch of the sampling location

(e)   Preliminary traverse data sheets including cyclonic flow checks

(f)   Raw field data sheets

(g)   Laboratory analytical sheets and case narratives

(h)   Sample calculations

(i)   Pretest and post-test calibration data

(j)   Chain of custody forms

(k)   Documentation of process and air pollution control system data

12.4 What nomenclature do I use in this method?

You must use the following nomenclature:

A = Area of stack or duct at sampling location, square inches.

A_n = Area of nozzle, square feet.

b_f = Average blockage factor calculated in Equation 25, dimensionless.

B_{ws} = Moisture content of gas stream, fraction

(e.g. 10% H_2O is $B_{ws} = 0.10$).

C = Cunningham correction factor for particle diameter, D_p, and calculated

using the actual stack gas temperature, dimensionless.

$\%CO_2$ = Carbon Dioxide content of gas stream, % by volume.

C_a = Acetone blank concentration, mg/mg.

C_{PM10} = Conc. of PM_{10} collectable particulate matter, gr/DSCF.

$C_{PM2.5}$ = Conc. of $PM_{2.5}$ collectable particulate matter, gr/DSCF.

C_p = Pitot coefficient for the combined cyclone pitot, dimensionless.

C_p' = Coefficient for the pitot used in the preliminary traverse, dimensionless.

C_r = Re-estimated Cunningham correction factor for particle diameter

equivalent to the actual cut size diameter and calculated using the

actual stack gas temperature, dimensionless.

C_{total} = Conc. of total collectable particulate matter, gr/DSCF.

C_1 = -150.3162 (micropoise)

C_2 = 18.0614 (micropoise/$K^{0.5}$)

= 13.4622 (micropoise/$R^{0.5}$)

C_3 = 1.19183 x 10^6 (micropoise/K^2)

= 3.86153 x 10^6 (micropoise/R^2)

C_4 = 0.591123 (micropoise)

C_5 = 91.9723 (micropoise)

C_6 = 4.91705 x 10^{-5} (micropoise/K^2)

= 1.51761 x 10^{-5} (micropoise/R^2)

D = Inner diameter of sampling nozzle mounted on Cyclone I, in.

D_p = Physical particle size, micrometers.

D_{50} = Particle cut diameter, micrometers.

D_{50-1} = Re-calculated particle cut diameters based on re-estimated C_r,
micrometers.

D_{50LL} = Cut diameter for cyclone I corresponding to the 2.25 micrometer cut
diameter for cyclone IV, micrometers.

D_{50N} = D_{50} value for cyclone IV calculated during the Nth iterative step,
micrometers.

$D_{50(N+1)}$ = D_{50} value for cyclone IV calculated during the N+1 iterative step,
micrometers.

D_{50T} = Cyclone I cut diameter corresponding to the middle of the overlap zone
shown in Figure 8 of the Tables, Diagrams, Flowcharts, and Validation
Data section of this method, micrometers.

I = Percent isokinetic sampling, dimensionless.

K_p = 85.49, [(ft/sec)/(pounds/mole -°R)].

m_a = Mass of residue of acetone after evaporation, mg.

M_d = Molecular weight of dry gas, pounds/pound mole.

M_w = Molecular weight of wet gas, pounds/pound mole.

M_1 = Milligrams of particulate matter collected on the filter, ≤ 2.5
micrometers.

M_2 = Milligrams of particulate matter recovered from Container #2 (acetone
blank corrected), >10 micrometers.

M_3 = Milligrams of particulate matter recovered from Container #3 (acetone
blank corrected), $\leq$10 and >2.5 micrometers.

M_4 = Milligrams of particulate matter recovered from Container #4 (acetone

blank corrected), ≤ 2.5 micrometers.

N = Number of iterative steps or total traverse points.

N_{re} = Reynolds number, dimensionless.

$\%O_{2,wet}$ = Oxygen content of gas stream, % by volume of wet gas.

[**Note:** the oxygen percentage used in equation 3 is on a WET gas

basis; that means that since O_2 is typically measured on a dry gas basis,

the measured $\%O_2$ must be multiplied by the quantity $(1 - B_{ws})$ to

convert to the actual volume fraction. Therefore $\%O_{2,wet}$ =

$(1 - B_{ws}) * \%O_{2dry}$]

P_{bar} = Barometric pressure, in. Hg.

P_s = Absolute stack gas pressure, in. Hg.

Q_s = Sampling rate for cyclone I to achieve specified D_{50}, ACFM.

Q_{sST} = Dry gas sampling rate through the sampling assembly, DSCFM.

Q_I = Sampling rate for cyclone I to achieve specified D_{50}, ACFM.

Q_{IV} = Sampling rate for cyclone IV to achieve specified D_{50}, ACFM.

R_{max} = Nozzle/stack velocity ratio parameter, dimensionless.

R_{min} = Nozzle/stack velocity ratio parameter, dimensionless.

T_m = Meter box and orifice gas temperature, °R.

t_n = Sampling time at point n, min.

t_r = Total projected run time, min.

T_s = Absolute stack gas temperature, °R.

t_1 = Sampling time at point 1, min.

v_{max} = Maximum gas velocity calculated from Equations 18 or 19, ft/sec.

v_{min} = Minimum gas velocity calculated from Equations 16 or 17, ft/sec.

v_n = Sample gas velocity in the nozzle, ft/sec.

v_s = Velocity of stack gas, ft/sec.

V_a = Volume of acetone blank, mL.

V_{aw} = Volume of acetone used in blank wash, mL.

V_c = Quantity of water captured in impingers and silica gel, mL.

V_m = Dry gas meter volume sampled, ACF.

V_{ms} = Dry gas meter volume sampled, corrected to standard conditions, SCF.

V_{ws} = Volume of water vapor, SCF.

W_a = Weight of residue in acetone blank wash, mg.

Z = Ratio between estimated cyclone IV D_{50} values, dimensionless.

ΔH = Meter box orifice pressure drop, in. W.C.

$\Delta H_{@}$ = Pressure drop across orifice at flow rate of 0.75 SCFM at standard

conditions, in. W.C. [**Note:** specific to each orifice and meter box]

$[(\Delta p)^{0.5}]_{avg}$ = Average of square roots of the velocity pressures measured during the

preliminary traverse, in. W.C.

Δp_m = Observed velocity pressure using S-type pitot tube in preliminary

traverse, in. W.C.

Δp_{max} = Maximum velocity pressure, in. W.C.

Δp_{min} = Minimum velocity pressure, in. W.C.

Δp_n =   Velocity pressure measured at point n during the test run, in. W.C.

Δp_s =   Velocity pressure calculated in Equation 24, in. W.C.

Δp_{s1} =   Velocity pressure adjusted for combined cyclone pitot tube, in. W.C.

Δp_{s2} =   Velocity pressure corrected for blockage, in. W.C.

Δp_1 =   Velocity pressure measured at point 1, in. W.C.

γ =   Dry gas meter gamma value, dimensionless.

μ =   Gas viscosity, micropoise.

θ =   Total run time, minutes.

ρ_a =   Density of acetone, mg/mL (see label on

                      bottle).

12.0   =   Constant calculated as 60% of 20.5 square inch cross-sectional area of

                      combined cyclone head, square inches.

12.5 What equations will I use in this method?

You will use the following equations to complete the calculations required in this test method.

Molecular Weight of Dry Gas. This equation is similar to the equation in Method 201A of Appendix M to 40 CFR part 51.

$$M_d = 0.44 \, (\%CO_2) + 0.32 \, (\%O_2) + 0.28 \, (100 - \%O_2 - \%CO_2) \quad\quad \text{Equation 1}$$

Molecular Weight of Wet Gas. This equation is identical to the equation shown in Method

201A of Appendix M to 40 CFR part 51.

$$M_w = M_d (1 - B_{ws}) + 18 (B_{ws})$$ Equation 2

Gas Viscosity. This equation is identical to the equation shown in previous versions of

Method 201A of Appendix M to 40 CFR part 51 with the exception that the constants

shown above are used for gas temperatures in °R, while the equation shown in Method

201A of Appendix M to 40 CFR part 51 had constants intended for gas temperatures in °F.

The latest released version of Method 201A of Appendix M to 40 CFR part 51 has a

viscosity equation that predicts values within 0.5% of Equation 1.

$$\mu = C_1 + C_2\sqrt{T_s} + C_3 T_s^{-2} + C_4 (\%O_{2,wet}) - C_5 B_{ws} + C_6 B_{ws} T_s^2$$ Equation 3

Cunningham Correction Factor. The Cunningham correction factor is calculated for a 2.25

micrometer diameter particle.

$$C = 1 + 0.0057193 \left[\frac{\mu}{P_s D_p} \right] \left[\frac{T_s}{M_w} \right]^{0.5}$$ Equation 4

Lower Limit Cut Diameter for Cyclone I for $N_{re} < 3162$. The Cunningham correction factor

is for a 2.25 micrometer diameter particle.

$$D_{50LL} = 9.507 C^{0.3007} \left[\frac{M_w P_s}{T_s} \right]^{0.1993}$$ Equation 5
$$(N_{re} < 3162)$$

Cut Diameter for Cyclone I for the Middle of the Overlap Zone.

$$D_{50T} = \left(\frac{11 + D_{50LL}}{2} \right)$$ Equation 6

Sampling Rate.

$$Q_s = Q_I = 0.07296(\mu)\left[\frac{T_s}{M_w P_s}\right]^{0.2949}\left[\frac{1}{D_{50T}}\right]^{1.4102}$$ Equation 7

Reynolds Number.

$$N_{re} = 8.64{\times}10^5\left|\frac{P_s M_w}{T_s}\right|\left[\frac{Q_s}{\mu}\right]$$ Equation 8

Meter Box Orifice Pressure Drop. This equation is identical to the equation presented in

Method 201A of Appendix M to 40 CFR part 51.

$$\Delta H = \left[\frac{Q_s(1-B_{ws})P_s}{T_s}\right]^2\left[\frac{1.083 T_m M_d \Delta H_@}{P_{bar}}\right]$$ Equation 9

Lower Limit Cut Diameter for Cyclone I for $N_{re} \geq 3162$. The Cunningham correction

factor is for a 2.25 micrometer diameter particle.

$$D_{50LL} = 10.0959 C^{0.4400}\left[\frac{M_w P_s}{T_s}\right]^{0.0600}$$

Equation 10
($N_{re} \geq 3162$)

Velocity of Stack Gas. Correct the mean preliminary velocity pressure for Cp and blockage

using Equations 23, 24, and 25.

$$v_s = K_p C_p (\sqrt{(\Delta p)})_{avg} \left| \sqrt{\frac{T_s}{P_s M_w}} \right|$$ Equation 11

Calculated Nozzle Diameter for Acceptable Sampling Rate.

$$D = \left[\frac{3.056 \, Q_s}{v_s} \right]^{0.5}$$ Equation 12

Velocity of Gas in Nozzle.

$$V_n = \frac{\left(\dfrac{Q_s}{60} \right)}{A_n}$$ Equation 13

Minimum Nozzle/Stack Velocity Ratio Parameter.

$$R_{min} = \left| 0.2457 + \left(0.3072 - \frac{0.2603 \, (\mu) \, (Q_s)^{0.5}}{v_n^{1.5}} \right)^{0.5} \right|$$ Equation 14

Maximum Nozzle/Stack Velocity Ratio Parameter. Equations 14 and 15 are identical to

equations presented in Method 201A of Appendix M to 40 CFR part 51.

$$R_{max} = \left| 0.4457 + \left(0.5690 + \frac{0.2603 \, (\mu) \, (Q_s)^{0.5}}{v_n^{1.5}} \right)^{0.5} \right|$$ Equation 15

Minimum Gas Velocity for $R_{min} \leq 0.5$.

$$v_{min} = v_n (0.5)$$ Equation 16

Minimum Gas Velocity for $R_{min} > 0.5$.

$$v_{min} = v_n R_{min}$$ Equation 17

Equations 16 and 17 are identical to equations presented in Method 201A of Appendix M to 40 CFR part 51.

Maximum Gas Velocity for $R_{max} \leq 1.5$.

$$v_{max} = v_n R_{max}$$ Equation 18

Maximum Gas Velocity for $R_{max} > 1.5$.

$$v_{max} = v_n (1.5)$$ Equation 19

Minimum Velocity Pressure.

$$\Delta p_{min} = 1.3686 \times 10^{-4} \left[\frac{P_s M_w}{T_s}\right]\left[\frac{v_{min}}{C_p}\right]^2$$ Equation 20

Maximum Velocity Pressure.

$$\Delta p_{max} = 1.3686 \times 10^{-4} \left[\frac{P_s M_w}{T_s}\right]\left[\frac{v_{max}}{C_p}\right]^2$$ Equation 21

Sampling Time at Point 1. N is the total number of traverse points. Equation 22 is

identical to an equation presented in Method 201A of Appendix M to 40 CFR part 51. You

must use the preliminary velocity traverse data.

$$t_1 = \left| \frac{\sqrt{\Delta p_1}}{(\sqrt{\Delta p})_{avg}} \right| \left[\frac{t_r}{N} \right]$$ Equation 22

Sampling Time at Point n. You must use the actual test run data at each point, n, and test

run point 1.

$$t_n = t_1 \frac{\sqrt{\Delta p_n}}{\sqrt{\Delta p_1}}$$ Equation 23

Adjusted Velocity Pressure.

$$\Delta p_s = \Delta p_m \left[\frac{C_p}{C_p'} \right]^2$$ Equation 24

Average Probe Blockage Factor.

$$b_f = \frac{12.0}{A}$$ Equation 25

Velocity Pressure.

$$\Delta p_{s2} = \Delta p_{s1} \left[\frac{1}{(1 - b_f)} \right]^2$$ Equation 26

Dry Gas Volume Sampled at Standard Conditions.

$$V_{ms} = \left[\frac{528}{29.92}\right][\gamma V_m]\left|\frac{\left(P_{bar} + \frac{\Delta H}{13.6}\right)}{T_m}\right|$$

Equation 27

Sample Flow Rate at Standard Conditions.

$$Q_{sST} = \frac{V_{ms}}{\theta}$$

Equation 28

Volume of Water Vapor.

$$V_{ws} = 0.04707 V_c$$

Equation 29

Moisture Content of Gas Stream.

$$B_{ws} = \left|\frac{V_{ws}}{V_{ms} + V_{ws}}\right|$$

Equation 30

Sampling Rate.

$$Q_s = \frac{29.92}{528}Q_{sST}\left[\frac{1}{(1 - B_{ws})}\right]\left|\frac{T_s}{P_s}\right|$$

Equation 31

Note: The viscosity and Reynolds Number must be recalculated using the actual stack

temperature, moisture, and oxygen content.

Actual Particle Cut Diameter for Cyclone I. This is based on actual temperatures and

pressures measured during the test run.

$$D_{50} = 0.15625\left[\frac{T_s}{M_w P_s}\right]^{0.2091}\left[\frac{\mu}{Q_s}\right]^{0.7091}$$

Equation 32

Particle Cut Diameter for $N_{re} < 3162$ for Cyclone IV. C must be recalculated using the

actual test run data and a D_{50} (D_p) of 2.5.

$$D_{50} = 0.0024302 \left[\frac{\mu}{Q_s}\right]^{1.1791} \left[\frac{1}{C}\right]^{0.5} \left[\frac{T_s}{P_s M_w}\right]^{0.6790}$$

Equation 33
($N_{re} < 3162$)

Particle Cut Diameter for $N_{re} \geq 3162$ for Cyclone IV. C must be recalculated using the

actual test run data and a D_{50} (D_p) of 2.5.

$$D_{50} = 0.019723 \left[\frac{\mu}{Q_s}\right]^{0.8058} \left[\frac{1}{C}\right]^{0.5} \left[\frac{T_s}{P_s M_w}\right]^{0.3058}$$

Equation 34
($N_{re} \geq 3162$)

Re-estimated Cunningham Correction Factor. You must use the actual test run Reynolds

Number (N_{re}) value and select the appropriate D_{50} from Equation 32 or 33 (or Equation 36

or 37 if reiterating).

$$C_r = 1 + 0.0057193 \left[\frac{\mu}{P_s D_{50}}\right]\left[\frac{T_s}{M_w}\right]^{0.5}$$

Equation 35

Re-calculated Particle Cut Diameter for $N_{re} < 3162$.

$$D_{50-1} = 0.0024302 \left[\frac{\mu}{Q_s}\right]^{1.1791} \left[\frac{1}{C_r}\right]^{0.5} \left[\frac{T_s}{P_s M_w}\right]^{0.6790}$$

Equation 36
($N_{re} < 3162$)

Re-calculated Particle Cut Diameter for $N_{re} \geq 3162$.

$$D_{50-1} = 0.019723 \left[\frac{\mu}{Q_s}\right]^{0.8058} \left[\frac{1}{C_r}\right]^{0.5} \left[\frac{T_s}{P_s M_w}\right]^{0.3058}$$

Equation 37
($N_{re} \geq 3162$)

Ratio (Z) Between D_{50} and $D_{50\text{-}1}$ Values.

$$Z = \frac{D_{50-1}}{D_{50}}$$ Equation 38

Acceptance Criteria for Z Values. The number of iterative steps is represented by N.

$$0.99 \le \left| Z = \left(\frac{D_{50_N}}{D_{50_{N+1}}} \right) \right| \le 1.01$$ Equation 39

Percent Isokinetic Sampling.

$$I = \left(\frac{100\, T_s V_{ms}\, 29.92}{60\, v_s \theta A_n P_s (1 - B_{ws})\, 528} \right)$$ Equation 40

Acetone Blank Concentration.

$$C_a = \frac{m_a}{V_a\, \rho_a}$$ Equation 41

Acetone Blank Weight.

$$W_a = c_a V_{aw\rho a}$$ Equation 42

Concentration of Total Collectable Particulate Matter.

$$C_{total} = \left(\frac{7000}{453,592} \right) \left| \frac{M_1 + M_2 + M_3 + M_4}{V_{ms}} \right|$$ Equation 43

Concentration of PM_{10} Collectable Particulate Matter.

$$C_{PM10} = \left(\frac{7000}{453,592} \right) \left| \frac{M_1 + M_3 + M_4}{V_{ms}} \right|$$ Equation 44

<u>Concentration of $PM_{2.5}$ Collectable Particulate Matter</u>.

$$C_{PM2.5} = \left(\frac{7000}{453,592} \right) \left[\frac{M_1 + M_4}{V_{ms}} \right]$$

Equation 45

13. METHOD PERFORMANCE

[Reserved]

14. POLLUTION PREVENTION

[Reserved]

15. WASTE MANAGEMENT

[Reserved]

16. REFERENCES

We used the following references in the development of this test method:

Dawes, S.S., and W.E. Farthing. "Application Guide for Measurement of $PM_{2.5}$ at

Stationary Sources," U.S. Environmental Protection Agency, Atmospheric Research

and Exposure Assessment Laboratory, Research Triangle Park, NC, 27511,

EPA-600/3-90/057 (NTIS No.: PB 90-247198), November 1990.

U.S. Environmental Protection Agency, Federal Reference Methods 1 through 5 and

Method 17, 40 CFR 60, Appendix A.

U.S. Environmental Protection Agency, Federal Reference Method 201A, 40 CFR 51,

Appendix M.

Richards, J.R. "Test protocol: PCA PM_{10}/$PM_{2.5}$ Emission Factor Chemical

Characterization Testing," PCA R&D Serial No. 2081, Portland Cement Association,

1996.

17. TABLES, DIAGRAMS, FLOWCHARTS, AND VALIDATION DATA

You must use the following tables, diagrams, flowcharts, and data to complete this test

method successfully.

Table 1. Typical Particulate Matter Concentrations

Particle Size Range	Concentration and % by Weight
Total collectable particulate	0.015 gr/DSCF
≤ 10 and > 2.5 micrometers	40% of total collectable particulate matter
≤ 2.5 micrometers	20% of total collectable particulate matter

Table 2. Required Cyclone Cut Diameters (D_{50})

Cyclone	Min. Cut Diameter, Micrometer	Max. Cut Diameter, Micrometer
PM_{10} Cyclone (Cyclone I from five stage cyclone)	9	11
$PM_{2.5}$ Cyclone (Cyclone IV from five stage cyclone)	2.25	2.75

Table 3. ΔH Values Based on Preliminary Traverse Data

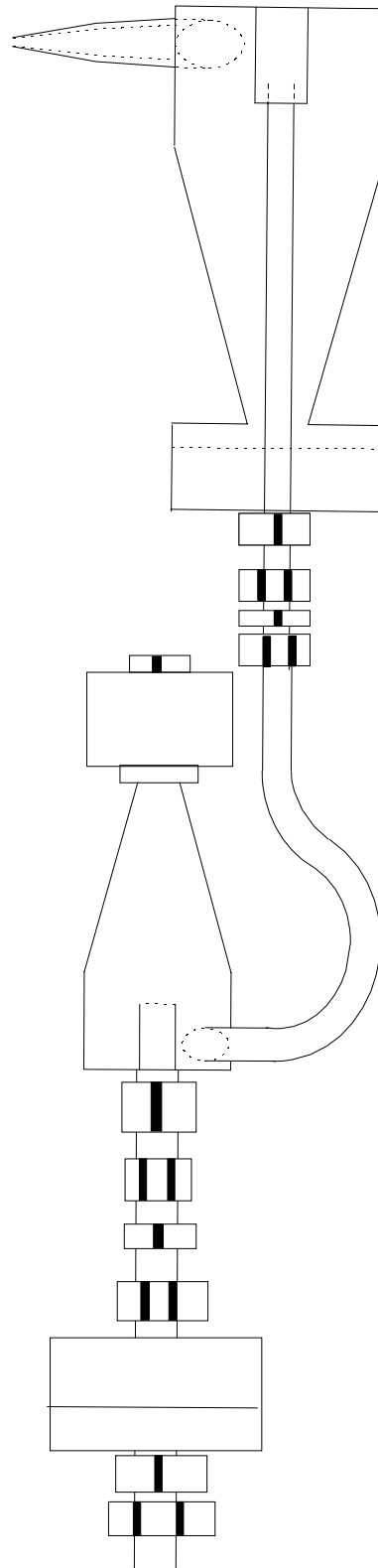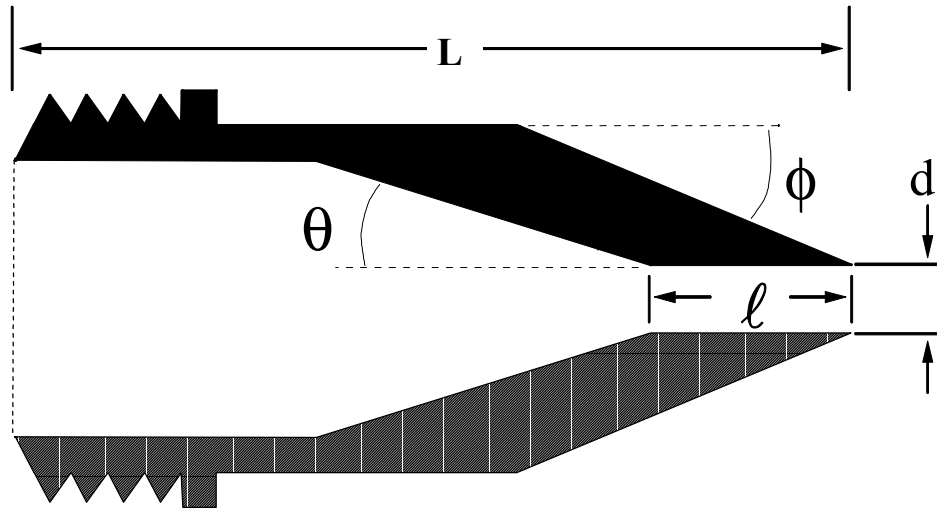| Stack Temperature, (°R)	$T_s - 50°$	T_s	$T_s + 50°$
ΔH, (in. W.C.)	-	-	-
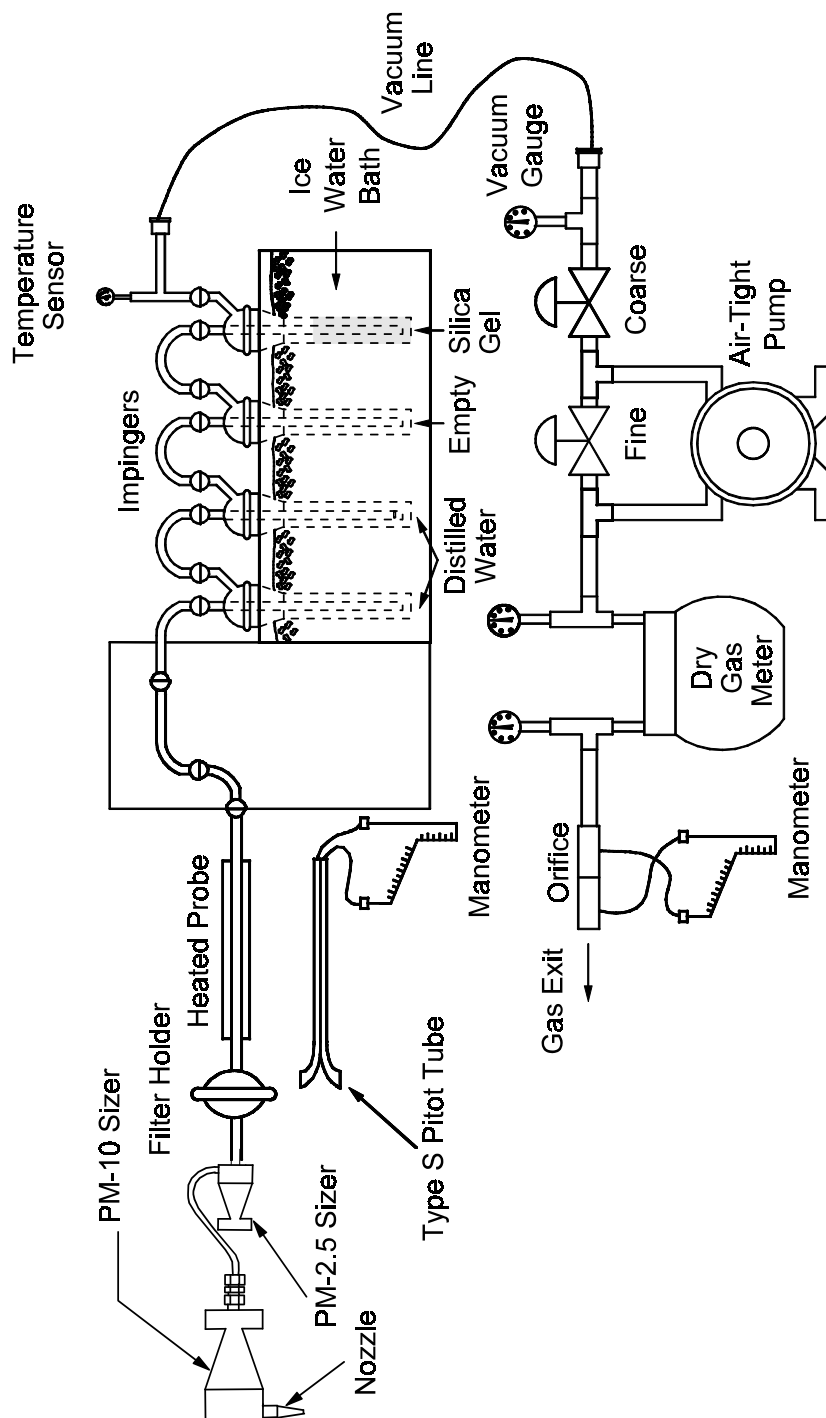
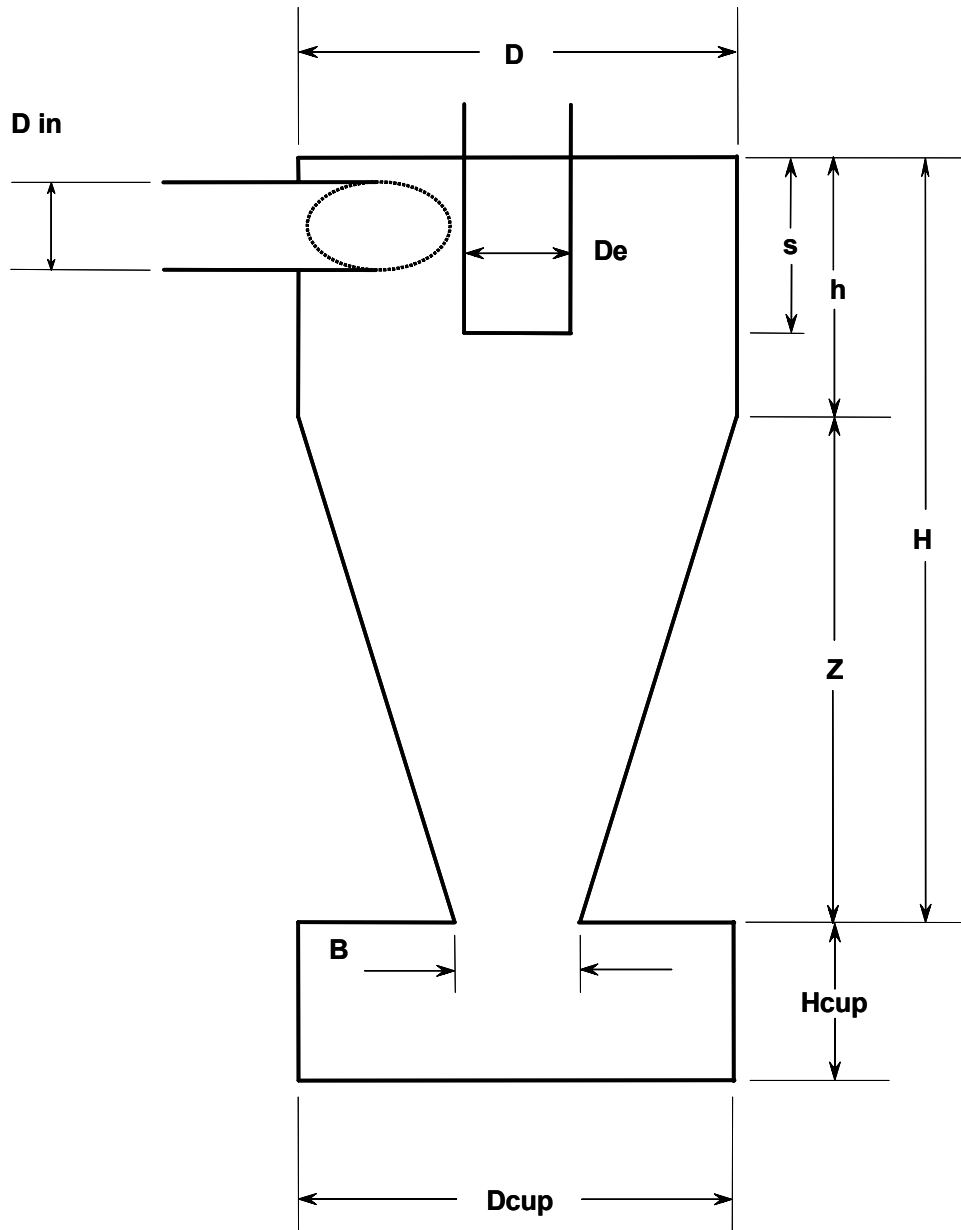Figure 1. In-Stack Sizing Device

Figure 2. Combined Cyclone Sampling Head

Nozzle diameter, d (inches)	Cone Angle, θ (degrees)	Outside taper, φ (degrees)	Straight inlet length, ℓ (inches)	Total Length, L (inches)
0.125	4	15	<0.05	2.710±0.05
0.136	4	15	<0.05	2.653±0.05
0.150	4	15	<0.05	2.553±0.05
0.164	5	15	<0.05	1.970±0.05
0.180	6	15	<0.05	1.572±0.05
0.197	6	15	<0.05	1.491±0.05
0.215	6	15	<0.05	1.450±0.05
0.233	6	15	<0.05	1.450±0.05
0.264	5	15	<0.05	1.450±0.05
0.300	4	15	<0.05	1.480±0.05
0.342	4	15	<0.05	1.450±0.05
0.390	3	15	<0.05	1.450±0.05

Figure 3. Nozzle Design Specifications
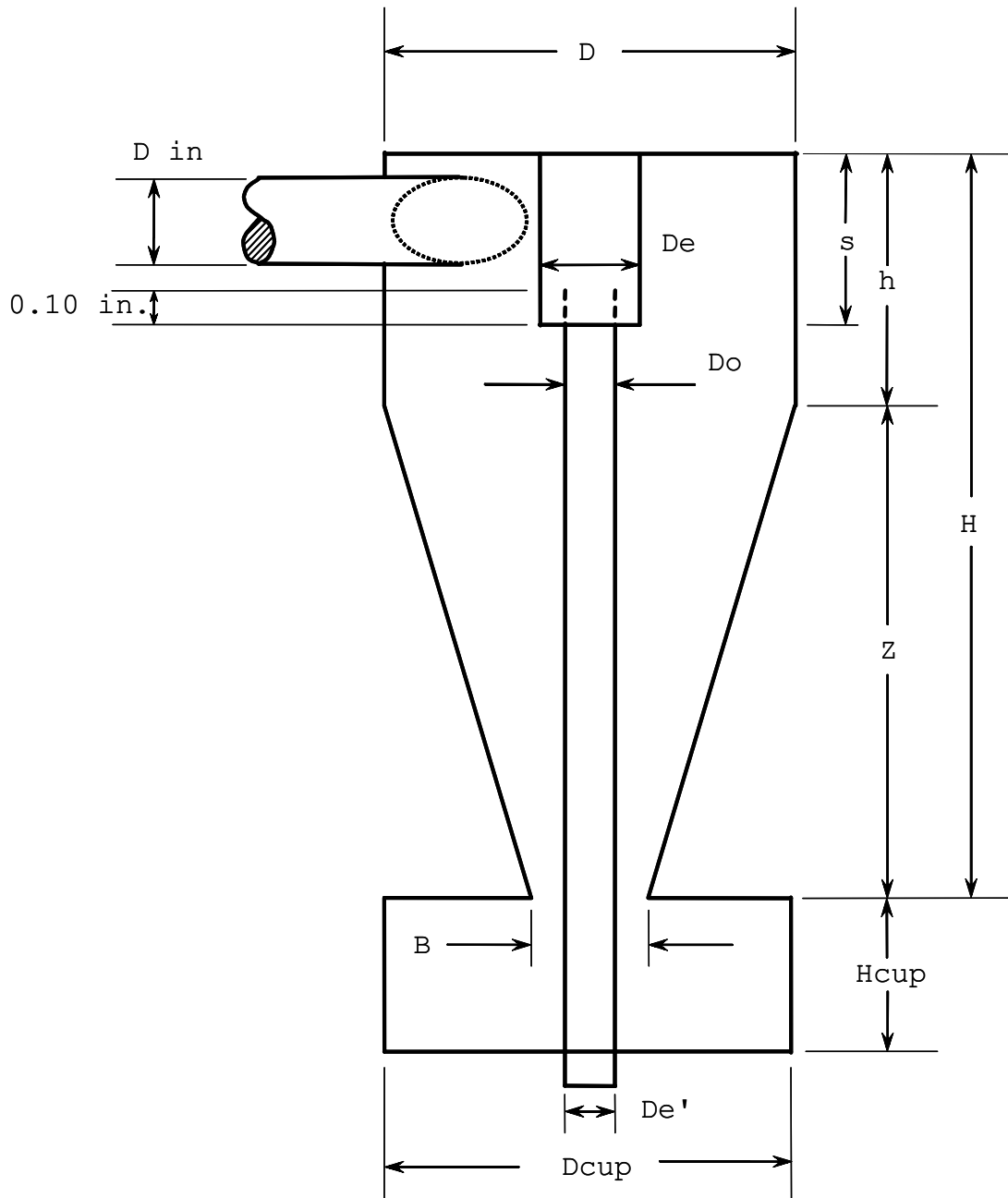
Figure 4. Design specifications for Cyclone I   (10 Micrometer)

Cyclone I	Cyclone Interior Dimensions (cm ± 0.02 cm)											
(10 Micrometer)	Din	D	De	B	H	h	Z	S	Hcup	Dcup	De'	Do
	1.27	4.47	1.50	1.88	6.95	2.24	4.71	1.57	2.25	4.45	1.02	1.24

Cyclone	Cyclone Interior Dimensions (cm ± 0.02 cm)									
IV	Din	D	De	B	H	h	Z	S	Hcup	Dcup
(2.5 Micrometer)	0.51	2.54	0.59	1.09	2.68	1.03	1.65	0.58	2.22	2.62

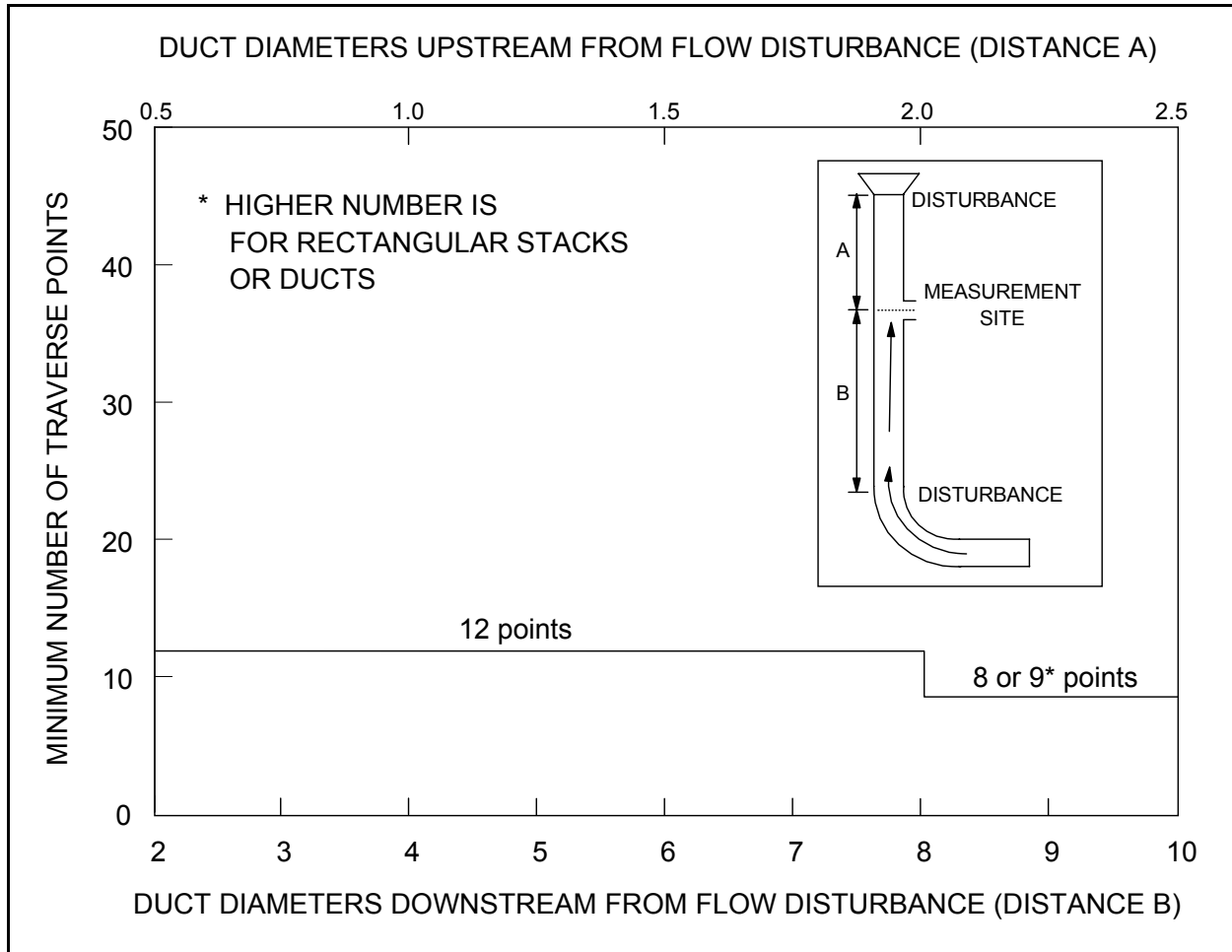Figure 5. Design Specifications for Cyclone IV (2.5 Micrometer) Sizing Device

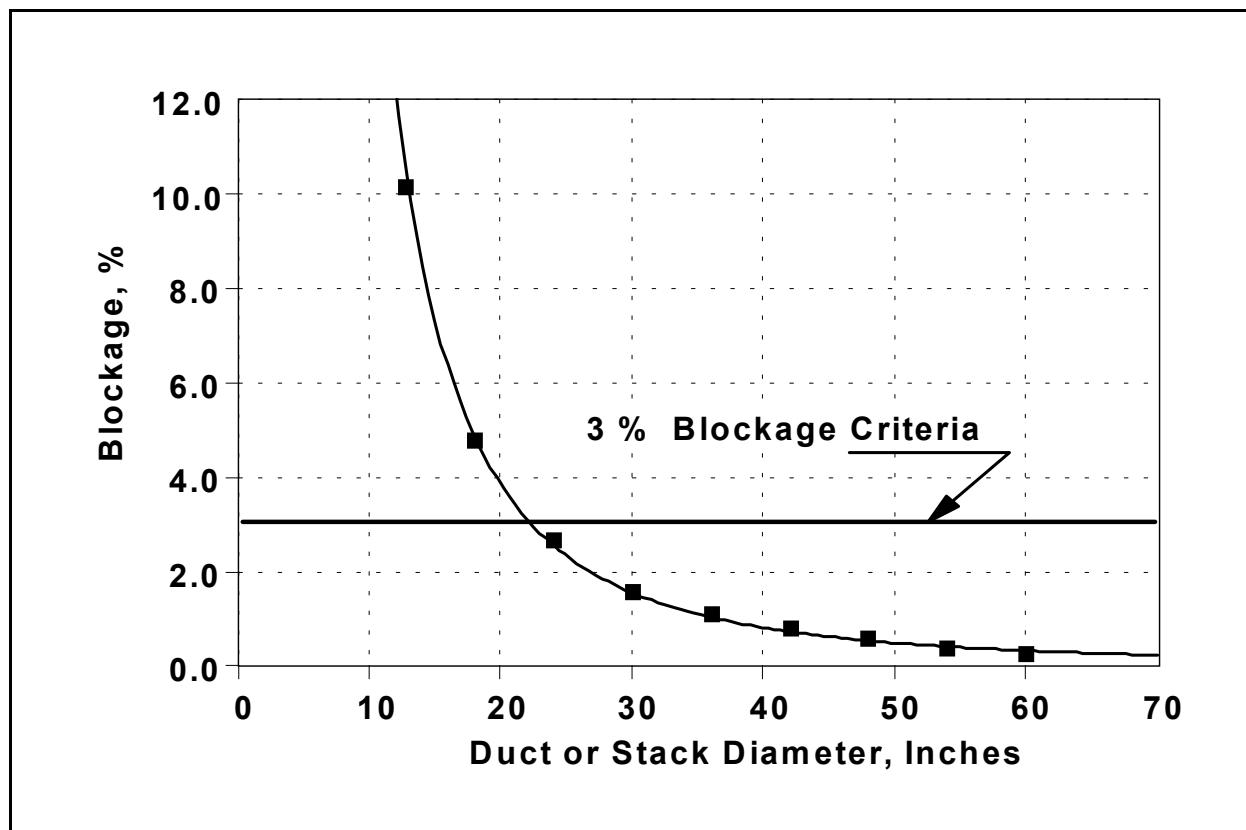Figure 6. Minimum Number of Traverse Points for Preliminary Method 4 Traverse

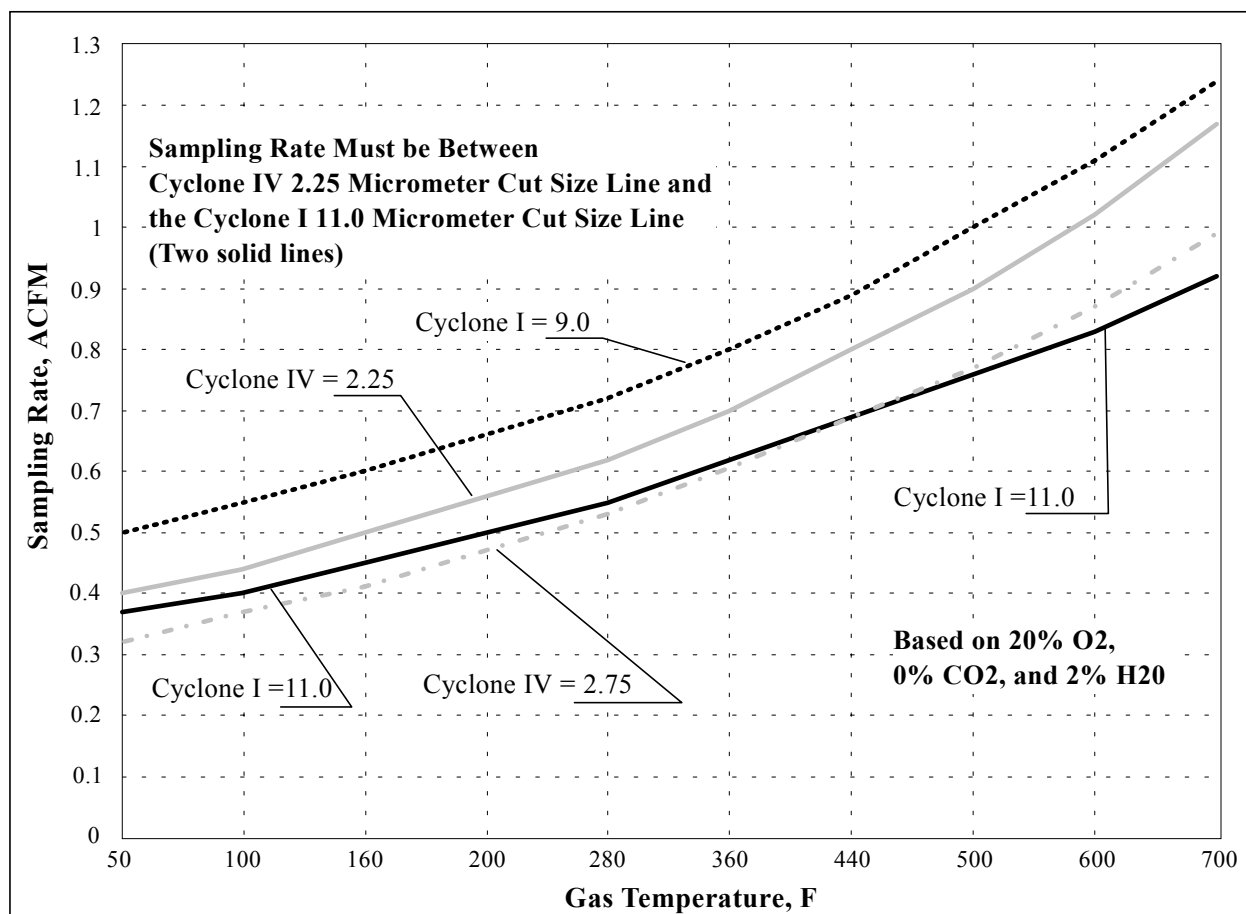Figure 7. Gas Flow Blockage by the Combined Cyclone Sampling Head

Figure 8. Acceptable Sampling Rate for Combined Cyclone Heads